Sustainability Shares in the Classroom

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Abstract

Safety shares, safety moments or toolbox talks are a way to keep process and personal safety at the front of mind. Within many industries every meeting, no matter what the topic, begins with a safety share, safety moment or toolbox talk, a chance to reflect on the importance of safety. The safety discussion might last for only 2 to 4 minutes and might be drawn from personal observation or experience or from readings. This practice has been replicated in one subject in the chemical engineering program at the University of Melbourne for seven years. A safety share begins every lecture. Safety shares, when implemented in a careful manner, allow students to be introduced to concepts such as permit-to-work, confined spaces, the hazards of static electricity and the importance of maintaining situational awareness.

If the use of safety shares has proved to be an effective way to raise the level of awareness of personal and process safety, then this technique can be expanded to promote the importance of sustainable development in the future. Lectures could begin with sustainability shares that introduce students to the key concepts. If safety shares can help promote a strong safety culture with a department or school, then the use of sustainability shares should be able to do the same.

In this paper the concept of sustainability shares is developed with 11 shares being proposed for use in the chemical engineering classroom. These shares cover topics including issues around energy equity in less developed countries, to the amount of embodied water and energy in some everyday items. By presenting one sustainability share a lecture, three lectures a week for a semester, almost 40 shares will be delivered by each subject helping students to understand the role that chemical engineers can play in addressing the issues of sustainable development.

1 Introduction

During the first decade of this century professional engineering institutions and associations have begun to recognize that engineering graduates must possess a strong and sound understanding of sustainable development concepts. Graduates will also need to understand that throughout their professional lives as engineers, many of their decisions will need to be guided by principles of sustainable development. In 2007, the UK-based Institution of Chemical Engineers released "A Roadmap for the 21st Century Chemical Engineering", a document that looks to the future of the chemical engineering profession (Institution of Chemical Engineers, 2007). An important observation made in the report is that the "… education of future generations of chemical engineers and realignment of the current generation with sustainability objectives is a vital component of the process of sustainable development." The report's authors also noted that the way in which sustainable development is taught in universities in the 2000s should be questioned just as the way concepts around safety were questioned in the late-1970s following the Flixborough accident in

1974 (Khan and Abbasi, 1999). Subsequent, updated versions of the IChemE's report including "chemical Engineering Matters" released in 2012 reemphasized the importance of sustainable water, energy and food as well as societal health and wellbeing.

In 2010 a number of leading engineers from around the world, sponsored by the United States National Academy of Engineering (2010), developed a list of fourteen grand challenges for the engineering profession as a whole for the 21st century. Five of these fourteen challenges are directly related to sustainable development – solar energy economics, energy from fusion, carbon sequestration methods, clean water access and managing the nitrogen cycle.

While the engineering profession on many levels now recognizes the importance of the philosophy of sustainable development professional accreditation bodies such as ABET in the US, Engineers Australia in Australia and ASIIN in Germany are silent as to how sustainable development concepts should be incorporated into the engineering curriculum.

In many ways sustainable development may be addressed in the engineering curriculum in fashions very similar to how concepts of personal and process safety and loss prevention are addressed in the chemical engineering curriculum. Both can be addressed through the use of standalone subjects that are delivered and assessed independently of all other content in the program, or the concepts may be integrated throughout the entire program. In this latter approach, the importance of sustainable development is emphasized in the first year of the program with concepts and relevant techniques being developed, leading towards some form of capstone project in which the key concepts learned must be applied. Whether standalone subjects are used or a more integrated approach is adopted, student learning may be reinforced through a school and university culture that recognizes the importance of sustainable development – a culture in which all institution staff behave in a manner that upholds the principles of sustainable development.

2 Safety Shares

The last two decades have seen the adoption of a practice throughout many industries in which safety is discussed at the start of every meeting, no matter what the topic of the meeting. The person running the meeting typically invites participants to share any safety-related issue or incident. These issues or incidents can be drawn from personal experience or from their wider knowledge. These discussion points, known as safety shares or tool box talks, may only last up to 5 minutes, but they act to keep safety at the front-of-mind.

The practice of opening every meeting with a safety share has been replicated by the author in every lecture in their undergraduate chemical engineering subject for the past seven years. Every one of these lectures has commenced with a short safety share of between 2 to 4 minutes (Shallcross, 2014). Although the students were advised that the contents of the safety shares would not be assessed they were advised that the shares would help them moving forward in their careers. A good safety share is one that students can easily relate to, not requiring specialist technical knowledge. Two simple safety shares are:

1) Methanol burns with a colourless flame. If any methanol is spilled then care must be taken approaching the pool of methanol. The methanol might be alight, but the only way someone can tell that is by the

heat given off. People have been burned as a result of a simple methanol pool fire as the flame is invisible.

2) In all facilities that process petrochemicals flare stacks are used to safely burn off the petrochemicals in an emergency. In the event of sudden loss of power, loss of process control or a blockage in a line that leads to a surge in pressure, the entire plant can be depressurised by dumping the liquids and gasses in the processing vessels and pipes to the flare. The radiant heat given off by the combustion of the petrochemicals at the flare can be so great that anyone in the vicinity of the flare at the time the chemicals are ignited risks severe burns. As the flare can be triggered without warning, entry into the area surrounding the flack stacks is usually strictly forbidden whenever the processing facility is in operation.

Over 50 other safety shares are presented by Shallcross (2014).

During 2013 and 2014 students enrolled in the class were asked to participate in a voluntary survey to gain insight into their opinions on the effectiveness of the safety shares to raise the awareness of safety in the profession. Using a paper-based, anonymous survey students were asked to state the extent to which they agreed or disagreed with a series of ten statements. A 5-point Likert scale was used in which a value of 1 was assigned to the response "Strongly disagree" while a value of 5 was assigned to "Strongly agree". The ten survey questions as well as the average responses from 107 respondents are presented in Table 1 (Shallcross 2014).

Although the results of this survey are described more fully in the 2014 paper it is useful to note here several key points:

1) every student agreed to some extent that chemical engineering graduates need a strong appreciation of the importance of safety;
2) 95 % of respondents recommended that the next time the subject was taught that safety shares be again incorporated into the start of the lectures; and,
3) less than 5 % felt that the safety shares were a waste of time.

The student response has been so strong that the practice has now spread to other subjects within the program.

3 Sustainability Shares

Given the success of the safety shares in raising the awareness of safety and safety-related issues amongst chemical engineering students it is reasonable to suspect that beginning some lectures with short discussion points related to sustainable development might be useful in promoting this important topic.

A series of short sustainability shares have been developed that may be used in the engineering class room to promote thought and possible discussion outside the lecture theatre. These are being tested during 2020 to determine their effectiveness in raising awareness of some of the key issues around energy, water and resource scarcity. Eleven of these shares follow.

Table 1 : Summary of survey responses with average score determined using a 5-point Likert scale.

Question	Average Score
Q1. I recommend that next time CPA1 is taught that the safety shares are again used to begin each class.	4.56
Q2. Chemical engineering graduates need a strong appreciation of the importance of safety.	4.78
Q3. I enjoyed hearing about the safety incidents described in the shares.	4.39
Q4. I would have liked the opportunity to participate more in the shares by sharing my own safety stories.	3.04
Q5. I did not pay much attention to the safety shares as they were not assessable material.	2.08
Q6. The safety shares were a waste of time. I would have preferred to get straight on with the lectures.	1.66
Q7. Most of the safety shares were interesting.	4.27
Q8. I would have liked to hear more safety shares.	3.80
Q9. The safety shares were a good way to introduce us to the importance of safety in the work place.	4.59
Q10. The safety shares were a good way to remind us of some of the dangers of working in chemical processing plants.	4.64

3.1 Bitcoin mining

Bitcoin mining currently accounts for around 0.2 % of the electricity consumed around the world. Iceland is a global hub for bitcoin mining and it is expected that in 2020 the amount of electricity consumed by this one area of e-commerce will surpass Iceland’s entire household electricity demand (International Energy Agency, 2018).

3.2 Billions of cars and trucks

The world’s fleets of cars and trucks increased from around 800 million in 2000, to 1350 million vehicles in 2017. China alone accounted for an increase in over 100 million vehicles during this period, with strong growth also occurring in India and Latin America. By 2040 the world’s vehicle fleets are predicted to pass 2 billion cars and trucks. The introduction of electric vehicles together with more fuel-efficient cars will mean that the demand for oil by road transport vehicles will only increase by 10 % over the period from 2017 to 2040, (International Energy Agency, 2018).

3.3 The legacy of offshore platforms

Since the world's first offshore oil platform not connected to land by a pier was built off the coast of California in 1932, over 16,000 offshore structures have been put into place for use in extracting oil and gas from subsea petroleum reservoirs. At the end of their useful lives these structures must be decommissioned and completely removed, with the seafloor being returned to its unobstructed state. The presence of so many structures that will eventually have to be removed, is a huge liability for the industry and society, and one that is often forgotten by the general public.

3.4 Power generation until 2040

As the global demand for power generation rises from 6960 GW in 2018 to an estimated 12480 GW in 2040, there will be a shift to more renewable energy sources. Despite the reduction in coal-based power generation in many Western countries, power demand is such that there will still be a nett increase in coal derived power generated until at least 2040.

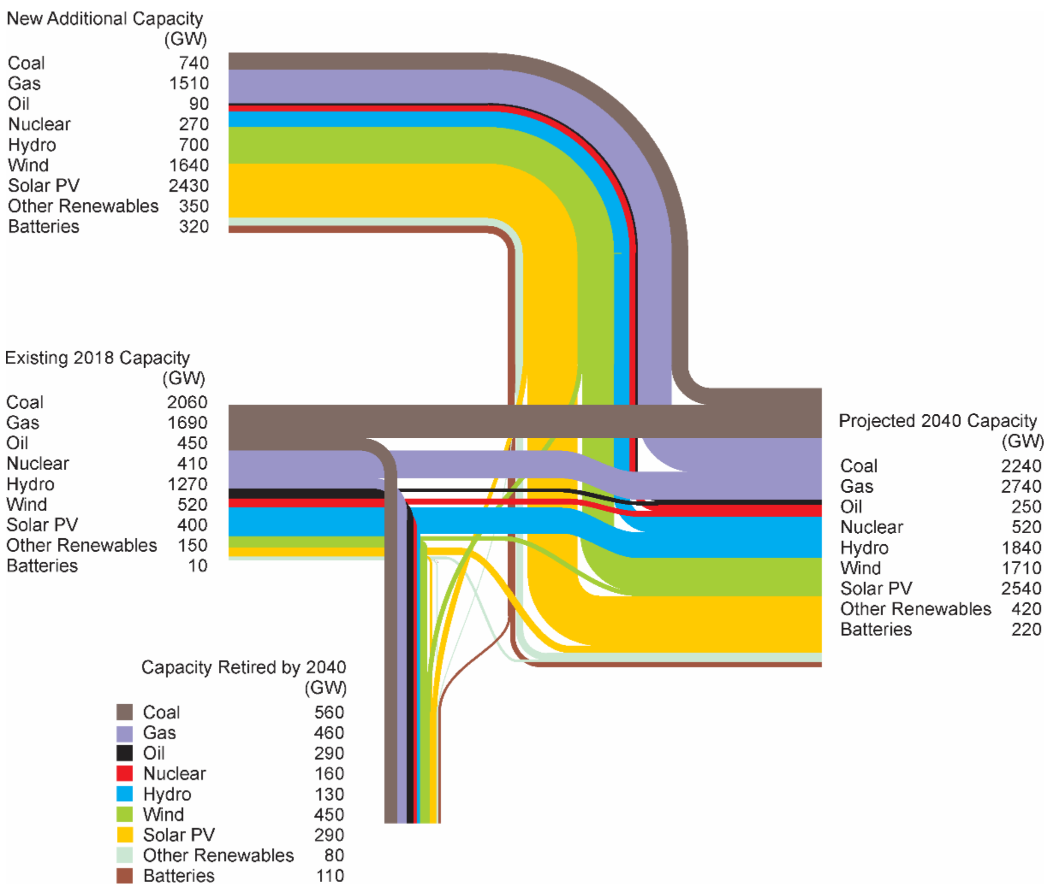

Figure 1 : Between 2018 and 2040 a large amount of generating capacity to be added around the world, while some will be retired. More than half the new capacity will come from renewable sources. Figure adapted from International Energy Agency (2018).

3.5 Data centre energy demands

The huge growth in the number of internet-connected devices around the world has led to a surge in the demand for electricity, not only to power these devices, but also to power the data centres associated with the use of these devices. In 2015 the world's data centres used around 191 TWh of electricity, representing about 1 % of the world's global consumption of electricity. Fortunately, the strong growth in demand for data centre services is countered by improved efficiencies in the way in which the centres are run. It is estimated that data centre power usage will remain stable at around 191 TWh until at least 2021, however beyond that time predictions cannot be made (International Energy Agency, 2018).

3.6 Recycling gold

What is the ultimate recyclable material? The answer is gold as throughout human history its value has been so high that it has never been thrown away – it is always recycled. The gold in the wedding ring my wife gave me might have been formed into a larger ring that was kept in a family as an heirloom for 150 years making its way from Spain to Australia in the 1970s. Before that the gold might have been mined in Russia and then traded as ingots, before being sold to a jeweller. Today gold is used in the electronics industry to create better electrical contacts. With mobile devices being disposed of without the gold being recovered, today, for the first time in history gold is being thrown away with little chance of recovery.

3.7 Energy consumptions rates in 2017

In 2017 the average worldwide energy consumption was 74.9 GJ per person per year (Figure 2). The per capita consumption rate for China is increasing and is now above the world average. If the per capita rates in China and India increase significantly then the demand on the world's energy resources will be overwhelming (Shallcross, 2020).

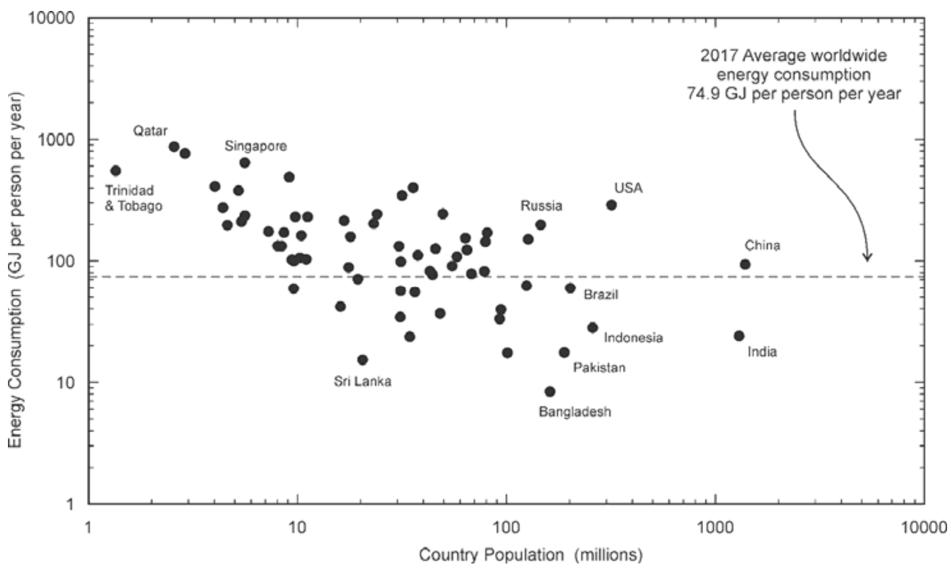

Figure 2 : Average energy consumption per person per year in 2017 for each country over 1 million, for which data is available (Shallcross, 2020).

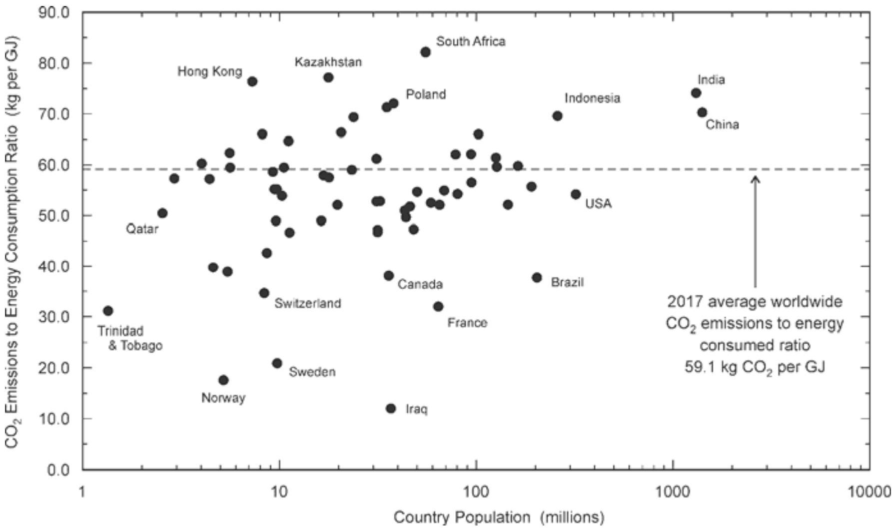

Figure 3: Average annual production of CO_2 emission to energy consumed for each country expressed in kg per GJ (Shallcross, 2020).

3.8 CO_2 production rates in energy production

Some countries produce their energy more cleanly with less CO_2 production than others. Figure 3 shows the average annual ratio of CO_2 emissions to energy consumed for each country with a population over 1 million, and for which data is available. France's high reliance on nuclear energy generates little CO_2, while other countries have a greater reliance on coal. (Shallcross, 2020).

3.9 Water for breakfast

How much water did you have for breakfast? If we include the embodied water in the two eggs (392 litres), the two slices of bacon (998 litres), the two slices of bread (146 litres), the pad of butter spread on the bread (28 litres) and the cup of tea (27 litres), then 1591 litres of water were embodied within the food. This does not include, however, the energy to cook the food, or boil the water for the tea. These are average values and may vary significant between locations.

3.10 Water footprint of different meats

It has been calculated that to produce 1 kg of beef for human consumption requires 15,400 litres of water, while lamb requires 10,400 litres of water per kg of meat, but pork only requires 6,000 litres of water per kg of meat. Chicken typically requires just 4,300 litres of water per kg of meat, just a quarter of the amount for beef. These figures will vary for different locations (Mekonnen and Hoekstra, 2012).

3.11 Availability of the elements

Whether it is lithium for batteries or platinum for catalysts some elements will increasingly become scarcer as the level of demand approaches supply levels. Figure 4 shows that within the next 100 years the availability of some elements such as zinc and silver will be seriously threatened.

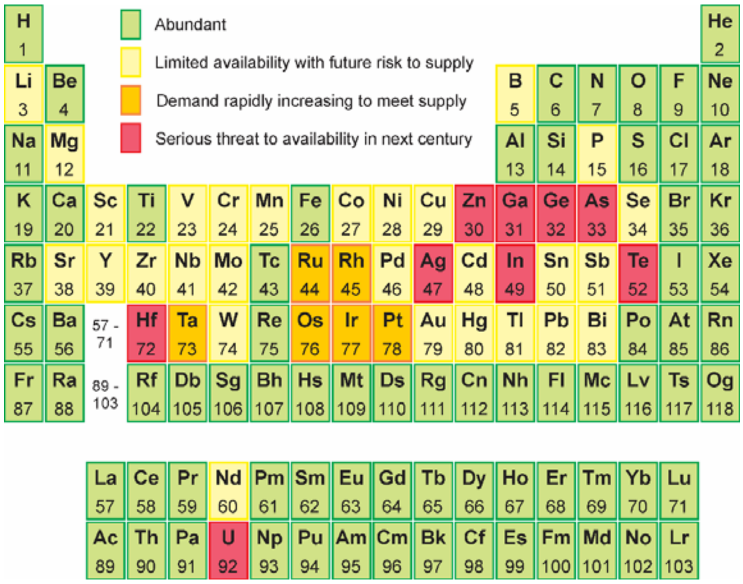

Figure 4 : Periodic table showing the future availability of some of the elements.

4 Concluding Remarks

Safety shares have proven to be useful in propmoting the importance of safety within the chemical engineering student community. It is anticipated that well developed sustainability shares will also prove to be useful in reinforcing concepts taught in other classes in an engineering program. Sustainability shares will be introduced into the chemcial engineering classrooms in a second year subject during the 2020 academic year in order to test their value. The results of this trial will be presented later.

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